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Acute kidney injury in renal trauma patients

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Abstract. Background: The kidney is the most commonly injured organ of the genitourinary system during trauma. We describe the associated risk factors for the development of acute kidney injury (AKI) in patients with renal trauma (RT). Materials and methods: We prospectively analyzed data from 65 patients who suffered RT from 2015 to 2019 at the Hospital Civil de Guadalajara. Demographic variables, clinical characteristics, and AKI risk factors were described. We assessed the risk factors related to AKI development. Results: In our study cohort, 60 (92.3%) patients were men, mean age 25 (20 – 30) years; the most common cause of RT was firearm injury in 26 (40%) of patients and 46 (70%) required surgery. AKI associated with RT developed in 39 (60%) patients. There were no differences between patients with or without AKI requiring nephrectomy (35.9 vs. 19.2%, p = 0.15). RT was classified as high-grade in 37 (56.9%) cases; high-grade RT increased four-fold the probability of AKI (adjusted OR 3.95, p = 0.05). A model for AKI prediction during RT was built with the most relevant variables: firearm injury, shock, emergency surgery, high-grade RT, and liver injury, all predicting AKI (ROC-AUC of 0.74 p = 0.02). Conclusion: AKI occurred in 60% of cases with RT, and it was significantly associated with high-grade RT. Further studies will be required to confirm this association in other populations, which could lead to an earlier and proactive management of AKI in this setting.

Introduction

Among organ failure after trauma, acute kidney injury (AKI) is common, with a reported incidence up to 50%, and is independently associated with prolonged hospitalization and higher mortality [1, 2]. Trauma patients are exposed to multiple risk factors for developing AKI, including systemic inflammation, hypovolemic shock, massive transfusion, rhabdomyolysis, abdominal compartment syndrome, and major surgery [3, 4]. AKI usually develops in the next days following multiple trauma, with 96% of the cases diagnosed within the first 5 days after traumatic injury [2]. Identifying AKI risk factors after multiple trauma is essential to establish a strategy aiming to prevent AKI and its related complications. Ryan et al. [5] developed several risk-prediction models for AKI after multiple trauma based on demographic, clinical, and biochemical data around intensive care unit admission; however, renal trauma (RT) was not taken into account. Harrois et al. [2] described some associated risk factors in the largest multicenter cohort of trauma patients who developed AKI, but RT was also missing. The kidney is the most frequently injured organ of the genitourinary system during abdominal trauma [6, 7]; the prevalence of traumatic renal injury in trauma patients is a rare complication, ranging from 0.3 to 3.25% [8, 9, 10, 11, 12, 13], and the most common mechanism is blunt trauma, accounting for 71 – 95% of cases [6, 8, 14, 15, 16]. Although it seems intuitive that direct damage to the renal parenchyma will affect renal function, and its severity will determine the development of AKI, little is known about the relationship between RT and AKI incidence. In this prospective cohort we describe the risk factors

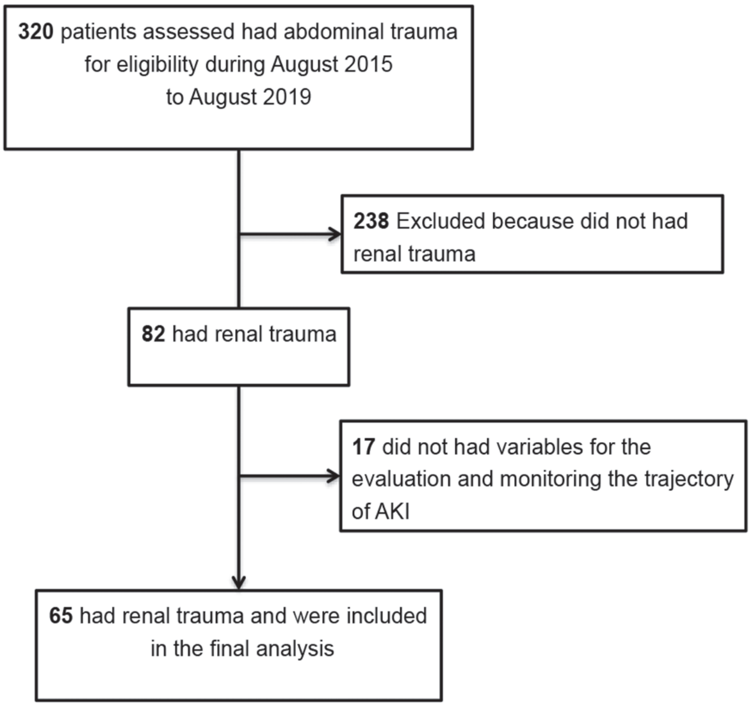

Figure 1. Flow chart of cohort study of patients with renal trauma.

associated with the development of AKI in patients with RT.

Materials and methods

A prospective cohort of patients with RT hospitalized between January 2015 to February 2019 at the Hospital Civil de Guadalajara, a trauma referral tertiary-care facility in Western Mexico. All patients had a clinical history and physical examination including vital signs, laboratory data, and strict fluid balance. Clinical characteristics and risk factors for development of AKI according to KDIGO guidelines [17] were analyzed.

Our primary aim was to describe the incidence of AKI in patients with RT, to identify risk factors associated with the development of AKI in these patients, and the variables associated with high-grade kidney trauma. Exclusion criteria included patients with chronic kidney disease (CKD) stage 5, chronic dialysis, and history of AKI and/or renal replacement therapy within the last 3 months, patients with incomplete medical records, and pregnancy.

This manuscript was drafted according to the specifications of The Strengthening the Reporting of Observational studies in Epidemiology STROBE guide for observational studies [18].

The Ethics and Research Committee of our institution waived the application of informed consent (HCG/CEI-0550/15), since patients were not exposed to additional risks.

Definition and classification

We used the American Association for the Surgery of Trauma (AAST) classification, which consists of an anatomic description, scaled from 1 to 5, representing the least to the most severe injury [19] (Online Supplemental Table 1). AKI was diagnosed by KDIGO serum creatinine (sCr) criteria [17] (Online Supplemental Table 2).

Baseline sCr was considered when the patient had a sCr of at least 3 months before hospitalization; in cases without baseline sCr, it was estimated using the Modification of Diet in Renal Disease, assuming a baseline estimated glomerular filtration rate (eGFR) of 75 mL/min/1.73m^2, as suggested by KDIGO guidelines [17].

Complications such as the incidence of liver, diaphragmatic, splenic, intestinal lesions, and transfusions during hospitalization were identified.

Statistical analysis

Continuous variables were reported as the mean (standard deviation (SD)) if they were normally distributed, or the median (interquartile range (IQR)) if they were not normally distributed, according to the Shapiro-Wilk test. A Mann-Whitney or t-test was used for comparison between groups, as appropriate. Categorical variables were expressed as proportions and were compared by χ^2-test or Fisher's exact test, as appropriate. Multivariate logistic regression was performed to identify risk factors associated to AKI. Calibration of the model was assessed using the Hosmer-Lemeshow goodness-of-fit test, considered as adequate when $p > 0.05$. For all other tests, p values were two-sided, and a value < 0.05 was considered statistically significant. MedCalc (Ostend, Belgium) was used for graphics and statistical analysis.

Table 1. Demographics and clinical characteristics of renal trauma patients according to AKI diagnosis.

	All N = 65 (%)	AKI n = 39 (%)	No AKI n = 26 (%)	p-value
Age (years)[+]	25 (20 – 30)	25 (21.2 – 30.7)	24 (17 – 30)	0.14
Gender (male, %)	60 (92.3)	36 (92.3)	24 (92.3)	1.0
NSAID (%)	10 (15.4)	7 (17.9)	3 (11.5)	0.48
Knife (%)	21 (32)	7 (17.9)	14 (53.8)	0.002
Firearm (%)	26 (40)	20 (51.3)	6 (23.1)	0.02
Blunt Trauma (%)	18 (27.6)	12 (30.8)	6 (23.1)	0.50
Transfusion (%)	43 (66)	27 (69.2)	16 (61.5)	0.52
Blood transfusion (%)	42 (64.4)	27 (69.2)	15 (57.7)	0.34
Red blood cell units[+]		2 (0-4)	1.5 (0-2)	0.15
Fresh frozen plasma transfusion (%)	22 (33.8)	15 (38.5)	7 (26.9)	0.33
Complication (%)	16 (24.6)	11 (28.2)	5 (19.2)	0.41
Shock (%)	21 (32.3)	16 (41)	5 (19.2)	0.06
AAST Renal Trauma Injury Grade[+]		4 (3 – 4)	2 (1 – 4)	0.01
Left kidney injury (%)	34 (52.3)	22 (56.4)	12 (46.2)	0.42
Emergency injury (%)	46 (70.7)	31 (79.5)	15 (57.7)	0.06
Nephrectomy (%)	19 (29.2)	14 (35.9)	5 (19.2)	0.15
Nephrorrhaphy (%)	24 (36.9)	15 (38.5)	9 (34.6)	0.75
Polectomy [Please check spelling] (%)	8 (12.3)	5 (12.8)	3 (11.5)	0.87
Nephrostomy (%)	6 (0.9)	4 (10.3)	2 (7.7)	0.72
Nephrology consultation (%)	12 (18.4)	10 (25.6)	2 (7.7)	0.06
Other injured organs (%)	55 (84.6)	34 (87.2)	21 (80.8)	0.48
Hepatic injury (%)	21 (32.3)	16 (41)	5 (19.2)	0.06
Diaphragmatic Injury (%)	13 (5)	7 (17.9)	6 (23.1)	0.61
Splenic injury (%)	15 (23)	10 (25.6)	5 (19.2)	0.55
Intestinal injury (%)	24 (36.9)	16 (41)	8 (30.8)	0.40
Length of stay (%)	19 (44.6)	11 (8 – 16)	8 (6 – 10)	0.04
Hemoglobin (g/dL)[^]	10.3 ± 2.8	10 ± 2.9	10.6 ± 2.8	0.45
sCr at admission (mg/dL)[^]	1.20 ±0.62	1.56 ± 0.91	0.85 ± 0.24	< 0.001
Serum urea at admission mg/dL[^]	45 ± 30	56 ± 41	34 ± 20	0.005
Serum sodium (mEq/L)[^]	134 ± 14	132 ± 20	136 ± 3	0.25
Serum potassium (mEq/L)[^]	4.3 ± 0.9	4.4 ± 1.1	4.2 ± 0.5	0.27

[+][redacted]; ^[redacted]; NSAID = non-steroidal anti-inflammatory drugs; AAST = American Association for the Surgery of Trauma.

Results

During the study period, 320 patients were admitted with diagnosis of abdominal trauma, 238 did not have RT, 82 had RT, and of these, 17 were excluded because of incomplete medical records, resulting in 65 patients included in the final analysis (Figure 1A, B ([redacted] no A or B in Figure 1)). Demographic and clinical characteristics of patients on admission according to AKI status are described in Table 1. 60 (92.3%) patients were men, (Figure 2); firearm was the mechanism in 26 (40%) of the patients, followed by stab wounds in 21 (32%), and blunt trauma in 18 (27.6%) patients. 43 (66%) patients received blood transfusions, and 46 (70%) required emergency surgery. Complications were reported in 16 (24.6%) patients. Nephrology was consulted in only 12 (18%) cases.

AKI developed in 39 (60%) patients, and the most frequent mechanism of trauma in this group was firearm wound (51.3 vs. 23.1%, p = 0.02). Severity grades by AAST classification were higher (4, range 3 – 4) in comparison to those who did not developed AKI (2, range 1 – 4), p = 0.04 (Figure 3). Length of hospital stay was higher in AKI patients in comparison to those without it (11, range 8 – 16 days vs. 8, range 6 – 10, days, p = 0.04).

sCr and serum urea on admission were higher in the AKI group (1.56 ± 0.91 mg/dL vs. 0.85 ± 0.24 mg/dL, p = < 0.001 and 56 ± 41 mmol/L vs. 34 ± 20 mmol/L, p = 0.005, respectively). Nephrectomy was similar in patients with and without AKI

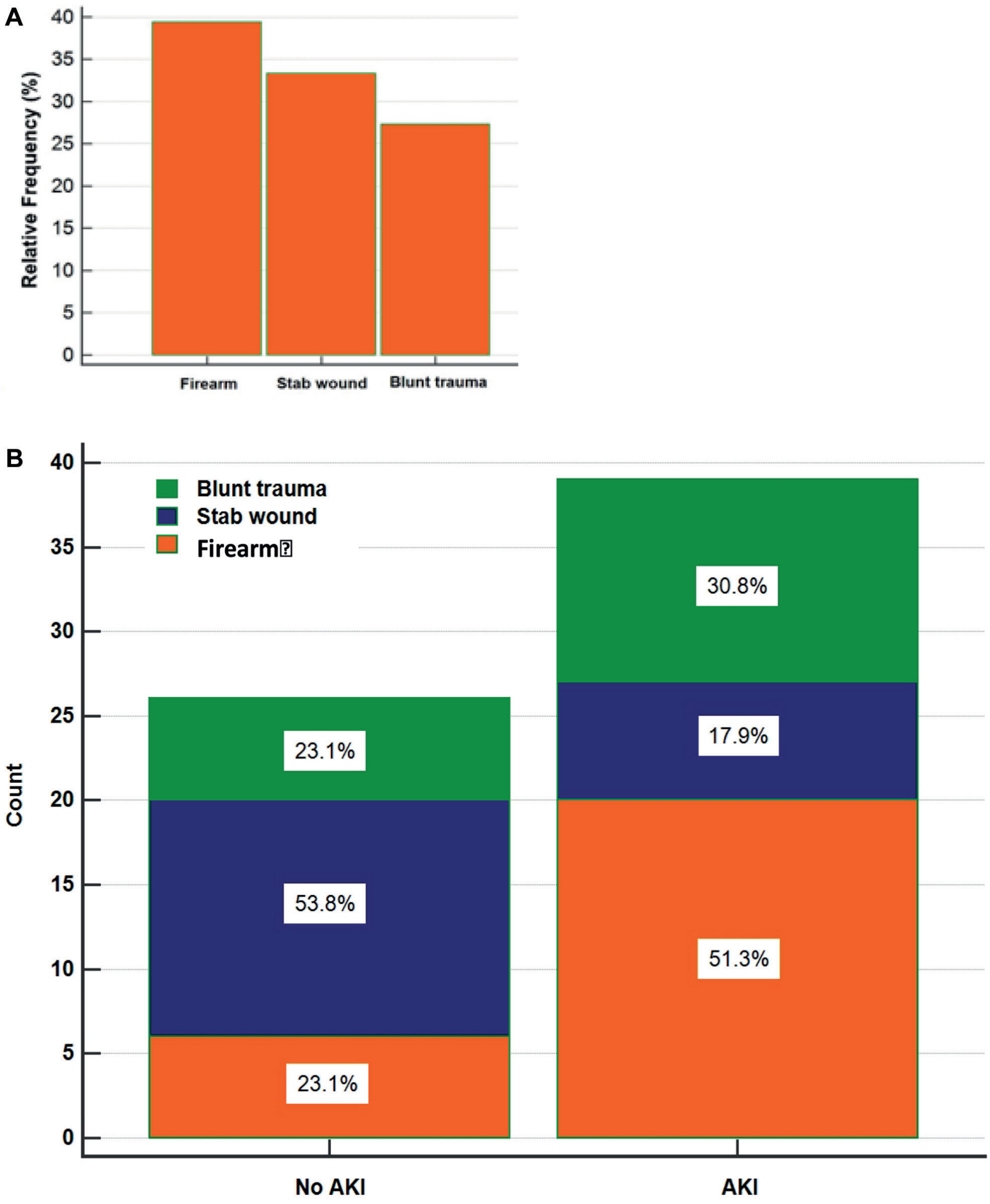

Figure 2. A: Distribution of mechanism of renal trauma; B: distribution of mechanism of renal trauma according to the presence of acute kidney injury.

5 (35.9 vs. 19.2%, p = 0.15); the left kidney was the more frequently injured organ (57%), followed by the bowel (37%), and liver (32%). Four patients died, all in the AKI group, and only 1 patient required dialysis.

Table 2 shows a subanalysis performed in patients with high (4 – 5) and low-grade (1 – 3) RT. Patients with high-grade RT had fewer injuries due to stab wound, had more firearm injury, required a higher number of blood transfusions, presented a higher number of hypotensive episodes, underwent more nephrectomies or nephrostomies, and developed more often AKI (p = < 0.05). A multivariate analysis was performed with forward stepwise regression method to identify the most relevant factors for the development of AKI, including the variables with p value < 0.20 at bivariate analysis; as expected, high-grade RT increased four-fold the probability of developing AKI (adjusted RR 3.95; 95% CI 0.90 – 17.2, p = 0.05) (Table 3). In the regression model, the 5 most relevant variables that predicted AKI were firearm injury, shock, emergency surgery, high-grade RT, and liver injury (p = 0.02, AUC 0.74).

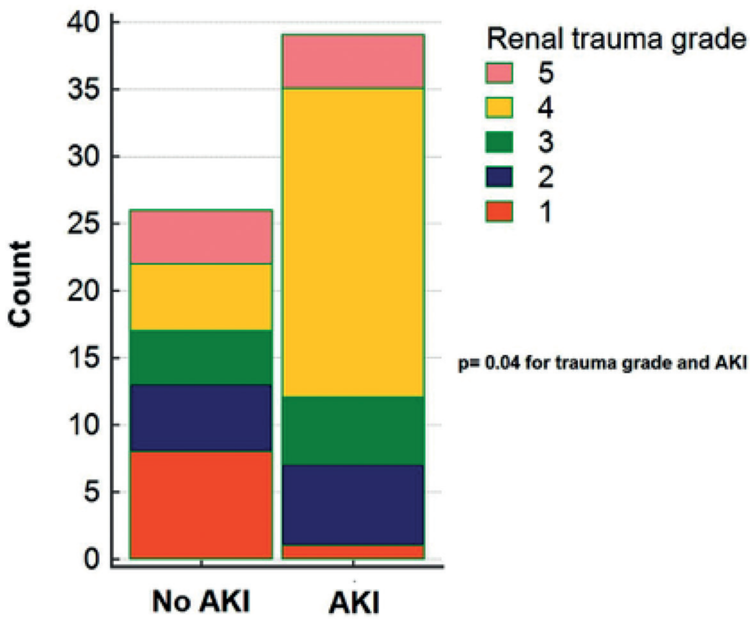

Figure 3. Distribution of mechanism of renal trauma according to the presence of acute kidney injury.

Discussion

In this prospective cohort, 60% of patients with RT developed AKI. To the best of our knowledge, the association between RT and AKI has never been explored before. Similar to other reports, male gender (92%) was more frequently affected [14, 21, 22, 30]. Patients were predominantly young, with a median age of 24 (20 – 30) years, similar in patients with or without AKI, but younger than previously reported [9, 14, 23]. Blood transfusion was indicated in 43 (66%) cases, and 46 (70%) patients required emergency surgery (Table 1). Nephrectomy was performed in 51% of the high-grade injury patients.

Penetrating RT is usually caused by firearm (83 – 86%) and stab wound (14 – 17%) [24, 25]. Indeed, firearm was the most frequent (40%) cause of RT in our study. These injuries tend to be more severe and to affect multiple organs, due to the direct tissue damage [26]. Patients with firearm injury have higher AAST grade than those with blunt trauma [27]. In our study, RT due to firearm injury was more frequently seen in AKI patients compared to those without AKI (20 vs. 6%, p = 0.02, respectively). RT due to blunt trauma was present in 18 (27.6%) cases and was the least frequent cause of RT in our study. Patients with AKI had less often stab wound lesions than those with no AKI (17.9 vs. 53.8%, p = 0.002), (Table 1).

Patients who developed AKI had more severe AAST RT grade, compared with those patients without AKI (4, range 3 – 4 vs. 2, range 1 – 4, p = 0.04) (Table 2) (Figure 3). In a previous report of 889 patients with kidney injury, 227 (25.5%) of the patients had severe kidney injury, however, AAST grades were not described [28]. Furthermore, the diagnostic criteria used to identify patients with AKI was not specified, a limitation that could erroneously estimate the true incidence and the associated risk factors related to AKI according to the current KDIGO classification. It is expected to find a higher incidence of AKI with a greater severity of RT. In fact, other authors [29, 30] have described the worst clinical outcomes in patients with higher RT AAST grades. The RT AAST grade also is a predictor for morbidity and mortality in blunt and penetrating renal injury [29]. Likewise, the AAST grade has a statistically significant correlation with the need for surgery (from 0 to 93%) and the risk of nephrectomy (0 – 86%) [30].

Nephrectomy has been associated with a higher incidence of AKI in comparison to other non-surgical interventions (4.6 vs. 0.6%, p < 0.001) (Table 1) [28]. Surprisingly, nephrectomy was not associated with an increased risk of AKI in our study, this finding could be explained because our patients are young and without comorbidities, which implies an adequate renal reserve that can solve the insult of renal trauma.

Nephrology referrals occurred in only 12 (18%) cases. Abdominal/pelvic IV contrast computed tomography (CT) with immediate and delayed images was the imaging technique of choice for defining the location and severity of injury [31]. Contrast CT could have been an additional exposure that could have increased the risk of AKI development, since nephrology consultation and prophylactic measures could have prevented contrast-induced AKI [32]. In our study, small bowel and liver were the most common organs affected (37 and 32%, respectively), similar data was previously reported by Parra-Romero et al. [33] in Mexico.

Trauma related to car accidents and violent aggressions are frequently reported in Mexico, representing 50% of deaths in the

Table 2. Clinical characteristics of renal trauma patients according to the AAST grade, high-grade was considered those 4 and 5, low-grade was considered 1,2,3.

	High grade n = 37	Low grade n = 28	p-value
Age (years)+	24 (20 – 29)	26 (17 – 32.5)	0.83
Knife (%)	8 (21.6)	14 (48.3)	0.02
Firearm (%)	20 (54.1)	6 (20.7)	0.006
Blunt trauma (%)	9 (24.3)	9 (31)	0.07
Transfusion (%)	29 (78.4)	15 (51.7)	0.02
Complication (%)	13 (35.1)	3 (10.3)	0.02
Shock (%)	16 (43.2)	5 (17.2)	0.02
AKI (%)	28 (75.7)	11 (39.3)	0.003
KDIGO 1 (%)	17 (60.7)	50 (50)	0.71*
KDIGO 2 (%)	8 (28.6)	20 (20)	0.69*
KDIGO 3 (%)	3 (10.7)	3 (30)	0.31*
Nephrectomy (%)	19 (51.4)	0	< 0.001
Nephrorrhaphy (%)	11 (29.7)	14 (48.3)	0.12
Polectomy [**Please check spelling**] (%)	6 (16.2)	2 (6.9)	0.25
Nephrostomy (%)	6 (16.2)	0	0.03
Nephrology consultation (%)	10 (27)	2 (6.9)	0.03
Other injured organs (%)	31 (83.8)	25 (86.2)	0.78
Hepatic injury (%)	14 (37.8)	7 (24.1)	0.23
Diaphragmatic injury (%)	7 (18.9)	7 (24.1)	0.60
Splenic injury (%)	8 (21.6)	7 (24.1)	0.81
Intestinal injury (%)	11 (29.7)	13 (44.8)	0.20
Length of stay (days)+	10 (6.5 – 16.5)	9 (6 – 11)	0.26

+■■■; *■■■; AKI = acute kidney injury; AAST = American Association for the Surgery of Trauma.

Table 3. Multivariate analysis of AKI in renal trauma patients.

	AKI	No AKI	RR	Adjusted RR	RR 95% CI	p-value
Firearm	20 (51.3)	6 (23.1)	1.57	1.93	0.54 – 6.88	0.30
Shock	16 (41)	5 (19.2	1.45	1.51	0.40 – 5.67	0.53
Surgery	31 (79.5)	15 (57.7)	1.60	0.83	0.17 – 3.96	0.82
High-grade renal trauma injury	28 (71.8)	9 (34.6)	1.92	3.95	0.90 – 17.2	0.05
Hepatic injury	16 (41)	5 (19.2)	1.45	1.98	0.52 – 7.45	0.31

AKI = acute kidney injury; RR = ■■[illegible]oodness-of-fit (Hosmer-Lemeshow). χ^2 = 3.61, p = 0.72; AUC, 0.74 (0.62 – 0.84).

15- to 44-year population [34]. It is expected that AKI will represent a frequent complication in this setting. Although injuries due to trauma represent a global problem, they are more frequent in low-income and low-middle income countries, where a robust health system to treat them is missing. 90% of the trauma injuries in the world occur in this context [35].

RT management has evolved during the last decades, with a clear transition toward a non-surgical approach [20, 36]. Traditionally, penetrating renal injuries were managed with exploration and nephrorrhaphy (61%), partial nephrectomy (48%), non-surgical exploration of the kidney, or nephrectomy [28]. For grade 1 and 2 AAST RT injuries, conservative management, with observation, bed rest, IV fluids, serial hematocrit monitoring, and antibiotics, is preferred [31], grade 3 or 4, should undergo exploratory laparotomy looking for other abdominal injuries [31]. For grade 5 type injuries, it is recommended to perform an exploratory laparotomy, but some groups recommend just observation for hemodynamically stable patients regardless of AAST grade, due to inter-observer variability regarding classification of grade 4 and 5 injuries [37]. This heterogeneity in management may explain the differences found between our study and previous reports. There were 4 deaths, and only 1 patient required dialysis, all in the AKI group.

Our study has a number of limitations; first, the small number of patients. Second, follow-up was short and limited to time spent in hospital; consequently, we do not know the long-term outcomes; third, the lack of a baseline sCr may underestimate AKI incidence; however, since this was a young and presumably healthy population, it is unlikely that chronic kidney disease was present in the majority of cases; fourth, our findings apply to mostly young males and is not representative across the two genders or to other populations; fifth, the incidence of renal trauma is much higher than what is reported in the literature, so this is clearly a high-risk population and not representative of the general population.

The strengths of our study are that, to the best of our knowledge, this is the first to describe the association between RT and the incidence of AKI, and it has a prospective design.

Conclusion

In summary, AKI occurred in 60% of cases with RT, and it was significantly associated to high-grade RT. Further studies will be required to confirm this association in other populations, which could lead to an earlier and proactive management of AKI in this setting.

Statement of ethics

Informed consent was waived since there were no interventions.

Acknowledgment

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None.

Conflict of interest

The authors declare no conflict of interest.

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